STORMWATER RUNOFF AND ASSOCIATED SEDIMENT CONTAMINATION IN THE POND C WATERSHED, MINNESOTA VALLEY NATIONAL WILDLIFE REFUGE

by

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LIST OF TABLES

LIST OF FIGURES

ABSTRACT

A nearshore area of Long Meadow Lake on the Minnesota Valley National Wildlife Refuge receiving stormwater runoff from a 2600-acre urban watershed was found in 1988 to have surface sediments heavily contaminated by heavy metals and polynuclear aromatic hydrocarbons (PAHs). In 1990, a survey of surface sediments in four stormwater detention ponds in that watershed was conducted to determine the extent and nature of their contamination. Sediments from all ponds were found to contain concentrations of several heavy metals and PAHs which individually exceeded biologically-derived "Lowest Effect Level" concentrations. An unrelated study found that the ponds contained a sparse benthic fauna comprised of contaminant-resistant invertebrate taxa.

When considered collectively, no positive correlation was found between the four ponds' stormwater detention times and the concentrations of heavy metals (represented by lead) or PAHs in their respective surface sediments. The data, which suggested that increased suspended solids settling times and the deposition of fine, more heavily contaminated sediments were unrelated, were found to be heavily skewed by the results for Pond C indicating that the pond having the longest stormwater detention time had the least contaminated surface sediments. This anomalous finding is believed to be the result of resuspension and downstream displacement of fine Pond C bottom sediments by intermittent, heavy stormwater flows through the pond. Such resuspended sediments would pass through the pond's outlet and be deposited in Long Meadow Lake. Several measures to mitigate the adverse contaminant-related effects of such an event are discussed.

TABLE OF CONTENTS

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INTRODUCTION

Contaminant surveys conducted on the Minnesota Valley National Wildlife Refuge in 1985 and 1988 identified two waterbodies having surface sediments heavily contaminated by constituents of urban runoff. Both Pond C (a five-acre Minnesota Department of Transportation highway/urban stormwater detention basin on Refuge property) and the nearshore area of Long Meadow Lake receiving the Pond C discharge were found to contain substantially elevated sediment concentrations of heavy metals and polynuclear aromatic hydrocarbons (PAHs) relative to other Refuge waters.

Runoff from nearly 2600 acres of fully developed residential, commercial and industrial property in the cities of Bloomington and Richfield, Minnesota, passes through an extensive storm sewer drainage network which discharges to the Pond C detention basin via two stormwater inlets (Figure). The southernmost of the two inlets carries runoff from a 2100-acre urban watershed. The majority of that runoff passes through from one to three upstream stormwater detention ponds before reaching Pond C and, subsequently, Long Meadow Lake. With 147 acre-feet of stormwater storage above its normal pool elevation, Pond C can provide detention for slightly less stormwater than is generated by a 4.2-inch (24-hour, 10-year) rainfall event over its watershed (City of Bloomington 1988). However, during the midpoint of a 2.3-inch (24-hour, one-year) rainfall event, removal of total suspended solids (TSS) and lead (a surrogate for other heavy metals) from the Pond C discharge has been estimated to be only 63 and 47 percent, respectively. During such an event, the total estimated mass of lead escaping Pond C into Long Meadow Lake during the first 20 hours is 8.25 kilograms at an estimated suspended sediment concentration of 1450 parts per million (ibid).

Long Meadow Lake is an important breeding and feeding area for mallards, wood ducks and other migratory birds. Refuge staff has been concerned for several years that contamination related to the Pond C and other stormwater discharges to the lake have been impairing its invertebrate productivity to an increasing degree over time. The Refuge has requested that the two municipalities and the Minnesota Department of Transportation either provide better suspended

solids and associated contaminant removal for the Pond C discharge or route the discharge away from Long Meadow Lake. A consultant for the City of Bloomington has suggested, among other alternatives, modification of the Pond C outfall structure to direct all stormwater generated by one-year or greater frequency rainfall events into other, larger Refuge ponds (Gravel Pit Pond or Kidder Marsh). The increased settling times for suspended sediments provided by the larger ponds should result in further water column TSS, heavy metal and PAH reductions prior to discharge to Long Meadow Lake at their respective outfalls. However, because neither pond has yet been as adversely impacted by urban runoff as Pond C (Gravel Pit Pond has a 375-acre urban watershed which is not likely to increase in size in future years), and because both have water quality conditions suitable for other Refuge purposes, the Refuge is reluctant to concur in a plan that would lead to further contamination of either. Even with implementation of the above-mentioned mitigation plan, rainfall events of less than a one-year frequency would continue to result in discharges of contaminated stormwater from Pond C to Long Meadow Lake. Further, the outfalls of either alternative treatment pond would constitute an additional point source contaminant concern for the lake.

The present study involved the collection and chemical analysis of surficial sediment samples from Pond C and, in ascending order up its watershed, Wright's Pond, Smith Park Pond, and Wilson Pond. In addition to receiving "detained" water from upstream detention ponds (Wilson Pond has no contributing upstream pond), each has a subwatershed from which it receives upland runoff during precipitation events. The study was an attempt to determine whether a relationship existed between those basins' stormwater detention times and their abilities to settle out finer, more contaminant-rich sediments. It was hoped that the information obtained would be useful in identifying measures to mitigate stormwater contaminant effects on Long Meadow Lake without sacrificing the water or sediment quality of other Refuge waterbodies.

METHODS

In July 1990, single surficial sediment samples, consisting of a composite of three individual, 10-centimeter deep Eckman dredge samples, were obtained from each of the above four ponds. The samples were obtained from areas approximately mid-pond, but never closer than 60 feet from pond outlets. Water depths at sampling locations ranged from 2.5 feet (Smith Park Pond) to 9.0 feet (Pond C). After mixing, sediment from each pond was portioned into chemically clean glass containers and frozen for shipment to analytical chemistry laboratories. Environmental Trace Substances Research Center, Columbia, Missouri, performed the analyses for heavy metals, grain size, and total organic carbon (TOC). Polynuclear aromatic hydrocarbon (PAH) scans were performed by the Mississippi State Chemical Laboratory, Mississippi State, Mississippi. Sediment chemistry data for Gravel Pit Pond are from a composite surface sediment sample obtained near mid-pond in 1985.

Engineers from the cities of Richfield and Bloomington were asked to provide information on drawdown times (the time required to draw down a pond from its

maximum stormwater storage elevation to its normal pool elevation through its outflow structure, assuming no inflow) for the ponds within their jurisdictions. Drawdown times calculated in this manner relate directly to the ponds' maximum stormwater storage capacities and to the size of outlet pipes. They do not take into account such factors as backwater effects in the outlet pipes (which can produce a retarding effect on drawdown rates), or the rate and duration of simultaneous inflows to the ponds (also a retarding effect). Consequently, the times represent minimums which would seldom be achieved in reality. However, if the above retarding effects were assumed to be essentially equal for all ponds in the system, drawdown times were believed to be potentially useful variables in examining the relationship between suspended sediment settling times and concentrations of selected contaminants in surficial sediments.

RESULTS AND DISCUSSION

Table 1 gives contributing watershed size, normal pool size and calculated drawdown times for the four Pond C watershed stormwater detention ponds. Table 2 provides heavy metal and PAH concentrations, grain size and total organic carbon content for sediments obtained from those ponds, and compares those data to heavy metal and PAH concentrations in sediment from Gravel Pit Pond. The Smith Park Pond sediment sample was the most heavily contaminated by metals and the second most contaminated by total PAHs. Wilson Pond sediment had the highest total PAH contamination, and was comparable to Wright's Pond sediment in terms of heavy metal contamination. The Pond C sediment sample was lowest of the four in both PAH and heavy metal contamination.

There was no positive correlation between drawdown times (indices of suspended sediment settling times) and concentrations of lead or total PAHs in sediment samples from the Pond C watershed stormwater detention ponds when viewed from a system-wide perspective. Nor were system-wide drawdown times positively correlated with the percent of fine particulates (silt and clay) in mid-pond sediment samples. At least two factors may account for this finding. First, as discussed earlier, all four detention ponds in the system receive substantial amounts of direct stormwater runoff from their own subwatersheds in addition to receiving "treated" stormwater from upstream ponds (Wilson Pond excepted). Each subwatershed differs somewhat in its mix of residential, commercial, industrial and highway acreage and in its ratio of pervious to impervious surfaces, leading to potentially differing proportions and rates of deposition of contaminants and particulates onto its soils and other surfaces, and differences in the sizes of particulates which are exposed to erosive forces. This was particularly apparent in the sediment samples for Smith Park Pond and Wright's Pond, which had notably heavy oily sheens on their surfaces and, not surprisingly, the highest total PAH concentrations.

Second, despite having a much longer drawdown time than the other detention ponds, Pond C mid-pond sediments obtained during the present study were less contaminated than those of any of the other detention ponds. Sediment samples collected in 1986 from the same area of Pond C showed contaminant

concentrations similar to those found for the three upstream ponds in the present study, suggesting that scouring and removal of finer bottom sediments at least as far as 75 feet from the Pond C outlet may be occurring periodically. Pond C is the only detention pond in the system having a bottom outlet and, coupled with its relatively short inlet-to-outlet distances compared to the other ponds, paths of increased water velocities along the pond's bottom between its inlets and outlet may be created during high discharge periods, resulting in the resuspension of finer, previously settled bottom sediments and reduced settling times for recently introduced suspended sediments moving along those paths. Even though the present Pond C composite sediment sample was obtained approximately 75 feet from the outfall structure, an increased water velocity effect is suggested by the high percentage of sand and relatively lower total organic carbon content of that sample. In effect, potentially substantial quantities of finer, more contaminated particulates entering Pond C during smaller storm events appear to be passed through to Long Meadow Lake during larger storm events. Heavy metal and PAH concentrations in Long Meadow Lake sediments collected near the Pond C outfall in 1988 clearly implicate that outfall as a contaminant source.

Included in Table 2 for comparative purposes are biologically-derived "Lowest Effect Level" heavy metal and PAH sediment concentrations developed by the Province of Ontario Ministry of the Environment (Persaud et al. 1990). A Lowest Effect Level represents a threshold level of sediment contamination which can be tolerated by the majority of benthic organisms, but above which adverse biological effects can begin to become apparent. Sediments from all four Pond C watershed stormwater detention ponds exceeded the Lowest Effect Levels determined for cadmium, chromium, copper, nickel, lead, zinc, and total PAHs. That fact is consistent with the findings of a 1990 invertebrate survey conducted by Refuge staff which found pollution-tolerant oligochaete worms (family: Aeolosomatidae) and bloodworms (family: Chironomidae) to be the only true benthic invertebrate representatives existing in any of the four ponds (Refuge 1990 file report).

CONCLUSIONS

The present study did not identify a relationship between suspended solids settling times (estimated by stormwater pool drawdown times) and the percentage of silt size and smaller particles or the concentrations of heavy metals or PAHs in surficial sediments for the Pond C watershed stormwater detention pond system as a whole. Factors likely accounting for this divergence from expectations include the unique contaminant mix contributed by each pond's subwatershed and the unexpectedly low contaminant concentrations found in the Pond C sediment sample. The latter finding suggests the development of an inlet-to-outlet bottom current in Pond C during larger runoff events sufficiently strong to cause scouring of fine bottom sediments accumulated during previous minor runoff events. That fine sediment and its associated contaminant burden, along with fine particulates introduced during the current runoff event, pass through the Pond C outfall and settle out in the nearshore zone of Long Meadow Lake. Pond C may be serving as little more than a temporary holding pond for those finer, more contaminated sediments.

All Pond C watershed stormwater detention ponds contain bottom sediments inhospitable to all but the most contaminant-resistant benthic invertebrates. While not pristine, the bottom sediments in Gravel Pit Pond are far less contaminated by heavy metals and PAHs and probably do not represent a toxicity threat to most benthic organisms. Routing Pond C outflows into Gravel Pit Pond or Kidder Marsh through the present outfall structure, however, would virtually assure the introduction of large volumes of contaminated fine sediments during larger runoff events, severely impacting the productivity of those waterbodies.

RECOMMENDATIONS

The degree of contamination of Long Meadow Lake sediments near the Pond C stormwater outfall appears to be related, in part, to the flushing of accumulated fine sediments from the latter during heavier runoff events. Routing of Pond C discharges directly to the Minnesota River via closed conduit is the only means of stopping the ongoing deterioration of the lake's nearshore aquatic habitat. In lieu of direct discharge to the Minnesota River or the use of Gravel Pit Pond or Kidder Marsh for enhanced settling of suspended solids, improvements to Pond C and its outfall appear to offer some hope for improving the quality of water reaching Long Meadow Lake. One such improvement would consist of raising the pond's outlet opening from its present location near the pond bottom to near the top of its existing permanent pool. This partial remedy was discussed in the City of Bloomington's December 1988 Pond C Detention Basin Water Quality Study. A more comprehensive remedy would involve raising the pond's berm and emergency spillway to provide increased stormwater storage while also raising its outlet opening to increase the depth of its permanent pool. Finally, it may be possible to install appropriately designed baffles or deflectors at both pond inlets in order to direct flow patterns away from the outlet, increasing residence times for incoming flows and reducing the bottom scouring which appears to be occurring at the present time.

TABLES

Table 1. Watershed size, normal pool size and detention pool drawdown times for stormwater ponds in the Pond C watershed (upstream to downstream).

Pond Name	Normal Pool Size (acres)	Watershed Size (acres)			Drawdown Time (hours)
		Untreated[a]	Treated[b]	Total	
Wilson Pond	4.0	467	0	467	12
Smith Park Pond	8.2	522	467	989	36
Wright's Pond	4.5	695	989	1684	4
Pond C	5.0	886	1684	2570	62

[a] Runoff comes directly off the urban landscape.

[b] Runoff passes through one or more upstream detention basins, experiencing some settling of suspended solids.

Table 2. Heavy metal and total PAH concentrations, percent total organic carbon (TOC) and grain size information for sediments in stormwater detention ponds in the Pond C watershed, and their comparison to Gravel Pit Pond and biologically derived "Lowest Effect Level" sediment concentrations.

	Concentrations (ppm, dry weight)					
Parameter	Wilson Pond	Smith Park Pond	Wright's Pond	Pond C	Gravel Pit Pond	Lowest Effect Level[a]
As	30	<20	<20	20	<6	6
B	13	18	14	10	2	--
Cd	2.8	4.0	2.9	1.3	0.4	1.0
Cr	51	54	57	36	31	31
Cu	78.1	95.0	80.4	43.8	38.1	25.0
Ni	33	43	42	34	31	31
Pb	380	553	521	110	20	31
Zn	431	554	426	205	129	120
Total PAHs	142.38	98.04	72.35	53.74	0.78	0.2[b] 0.1[c]
TOC (%)	10.7	9.4	9.6	5.0	--	--
Sand(%)	38.9	9.0	8.9	26.4	--	--
Silt (%)	52.7	72.1	79.4	60.2	--	--
Clay (%)	8.4	18.9	11.7	13.4	--	--

[a] A threshold concentration of sediment contamination which can be tolerated by the majority of benthic organisms. Above this level, adverse biological effects can begin to become apparent (Persaud et al. 1990).
[b] at 10% TOC.
[c] at 5% TOC.

FIGURES

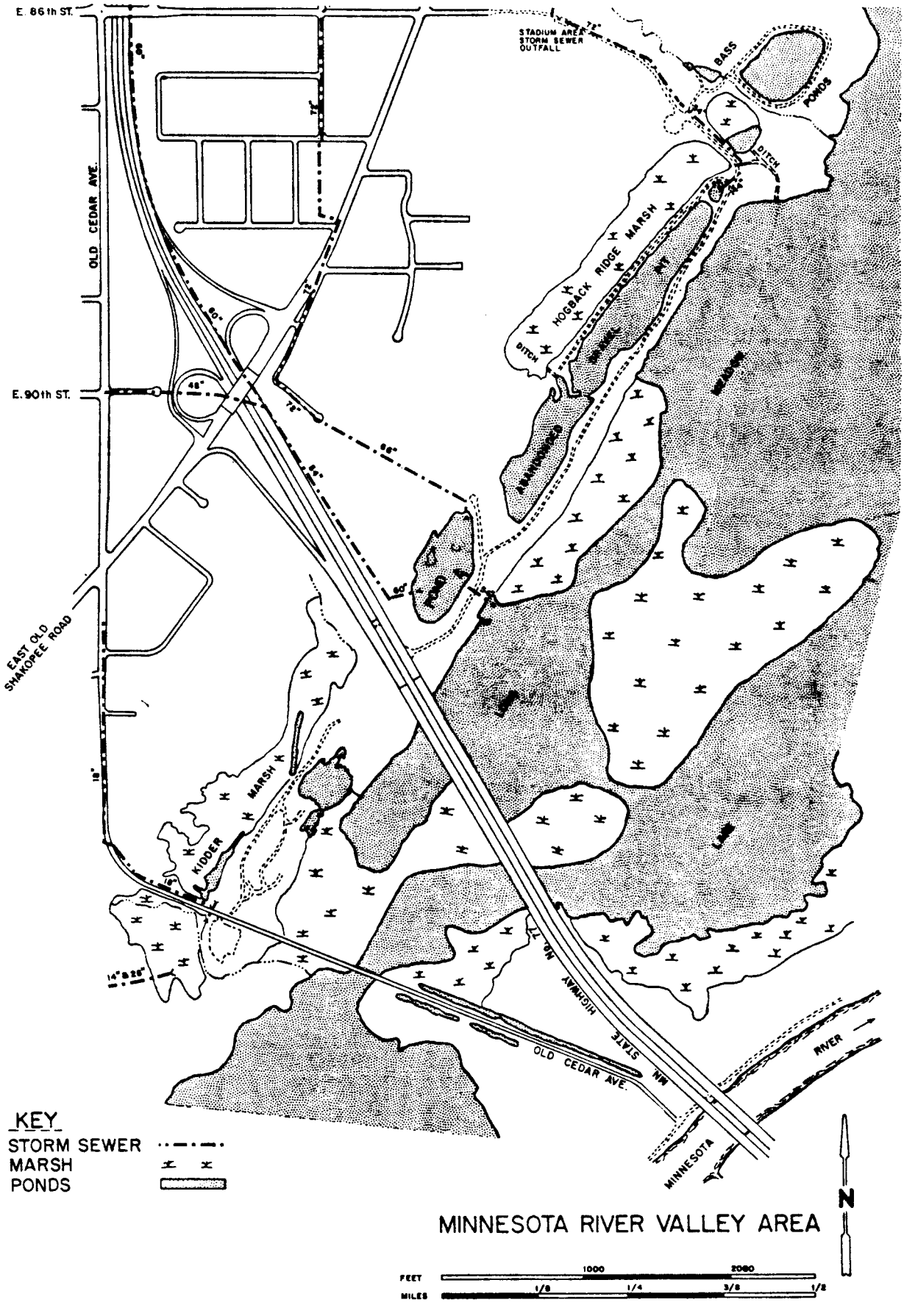

Figure. Present Pond C watershed stormwater route to Long Meadow Lake, Minnesota Valley National Wildlife Refuge.

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